(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 February 2001 (15.02.2001)

PCT

(10) International Publication Number
WO 01/10595 A1

(51) International Patent Classification[7]: B23P 17/00, B05D 3/12, B65D 65/28, B24B 19/00, G11B 5/82

(21) International Application Number: PCT/US00/21301

(22) International Filing Date: 4 August 2000 (04.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

09/369,030	4 August 1999 (04.08.1999)	US
09/565,871	5 May 2000 (05.05.2000)	US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier applications:

US	09/369,030 (CIP)
Filed on	4 August 1999 (04.08.1999)
US	09/565,871 (CIP)
Filed on	5 May 2000 (05.05.2000)

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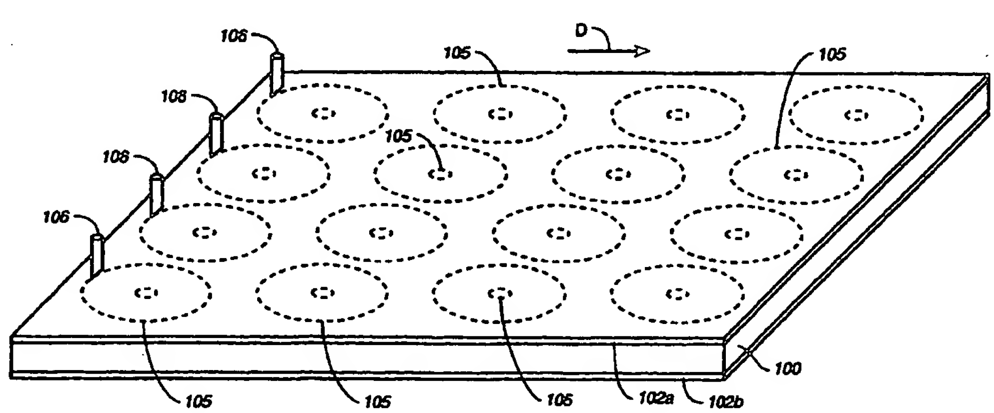
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*
— *With amended claims.*

[Continued on next page]

(54) Title: METHOD FOR MANUFACTURING A MAGNETIC DISK COMPRISING A GLASS SUBSTRATE



(57) Abstract: A method for manufacturing a glass substrate (110) for use in magnetic disk manufacturing comprising the steps of a) forming a glass sheet (100); b) forming a protective sheet (102a, 102b) over one or both sides of the glass sheet; c) cutting the glass sheet into workpieces (104); d) cutting the workpieces into disk-shaped substrates (110); e) subjecting the edges of the substrates to an edge polishing process; and f) removing the protective layer. Of importance, by leaving the protective layer over the substrate, the substrate surface is protected from damage.

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METHOD FOR MANUFACTURING A MAGNETIC DISK COMPRISING A GLASS SUBSTRATE

BACKGROUND OF THE INVENTION

This invention pertains to methods for making magnetic disks comprising glass substrates. This invention also pertains to methods for making glass substrates. This invention also pertains to methods for processing sheets of glass into workpieces.

It is known in the art to manufacture magnetic disks (e.g. disk 1 of Fig. 1) by sputtering an underlayer 2 (e.g. Cr or a Cr alloy); a magnetic alloy 3 (e.g. Co, a Co alloy or a Fe alloy); and a protective overcoat 4 (e.g. carbon) on a disk-shaped glass substrate 5. Substrates used in the manufacture of magnetic disks must be extremely flat and smooth. Accordingly, a great deal of effort and expense is taken to polish glass during the manufacture of substrates.

A typical process for manufacturing glass substrates is as follows.

1. First, a sheet of glass 10 (Fig. 2) is formed using a float or draw method. Glass produced by these methods is typically very smooth.
2. Glass sheet 10 is cut into individual squares 12 (typically 100mm by 100mm, with a thickness of about 1mm).
3. Thereafter, disk-shaped substrates 14 are cut out of squares 12. This requires cutting a centrally defined circular inner portion 16 and an outer portion 18

away from squares 12. This is accomplished using a sawing process or a scribing and breaking process.

4. Chamfers 22 are formed at the inner and outer diameter edges 24, 26 of substrate 14. (Fig. 3 illustrates substrate 14 in cross section, and shows chamfers 22.) This is generally a difficult operation. It is accomplished using multiple lapping and polishing steps.

5. Substrates 14 are then finished so that their surfaces are very smooth and have few or no defects. This is accomplished through one or more lapping or grinding steps and one or more polishing steps.

The grinding, lapping and polishing steps described above are extremely time consuming and expensive. During these steps, as much as 250 to 1000 μm of glass are removed to ensure that the resulting substrate is extremely flat and smooth, e.g. having an Ra of about 2 to 4Å. (Typically, glass as formed by the float or draw methods is very smooth, but not very flat. Chamfering and various manufacturing steps described above introduce scratches and damage into the glass surface. Thus, polishing is performed to a) make the substrates flat, and b) cause the glass to once again be smooth.) To do this, the polishing steps add a great deal of manufacturing cost to the substrates. It would be desirable to find a way to eliminate the need for such polishing.

SUMMARY

It has been discovered that one of the reasons such extensive polishing is required during the manufacture of magnetic disks is that glass splinters lodge on the surface of the glass during the various manufacturing steps described above. These splinters scratch and damage the glass surface, thereby necessitating extensive lapping

and polishing. By providing a protective layer over the glass during the various manufacturing steps, the need for such extensive processing is minimized.

In one embodiment, in lieu of chamfering the substrate edges, the substrate edges are rounded with an edge polishing technique. Whereas in the prior art, it was a foregone conclusion that the substrate would have to undergo extensive lapping and polishing (e.g. as a result of chamfering), it has been discovered that such lapping an polishing can be substantially avoided or minimized. Because of this, in a process in accordance with the present invention, it is advantageous to protect a glass workpiece with a protective layer.

In accordance with one embodiment of the present invention, a protective layer is formed at the beginning of a glass manufacturing process, e.g. when the glass is in the form of a sheet. The protective layer is then removed after the glass is put into its final form (e.g. a glass substrate for disk manufacturing). Thus, in this embodiment, the protective layer stays on the glass through much or all of the substrate manufacturing process, and is removed at or near the end of the substrate manufacturing process.

In accordance with another embodiment of the present invention, the protective layer is placed on a glass workpiece before the workpiece is subjected to a process step during which the workpiece can be damaged. After the process step, the protective layer can be removed. This process step can be sawing, scribing, breaking, transporting the glass from one work station to another, edge polishing substrates, stacking substrates, chamfering substrates (e.g. using a laser or mechanical means), or other process step. Protective overcoats can be placed on the glass and removed from the glass at several times during the manufacturing process. In accordance with some

embodiments of the invention, a protective overcoat can be place on a workpiece during single-workpiece processing or transporting.

One embodiment of a method in accordance with the invention begins with the step of providing a glass sheet. The glass sheet is typically formed by the float method. However, the glass sheet can be formed by other techniques such as drawing.

One and typically both sides of the glass sheet are then covered with a protective layer. The protective layer can be a polymer or other material, and protects the surface (or surfaces) of the glass sheet from splinters and other contaminants. Of importance, the protective layer prevents the surface of the glass sheet from being scratched by these particles.

After being covered with a protective layer, in one embodiment, the glass sheet is cut into smaller workpieces. This can be done by any of a number of methods, e.g., sawing or scribing and breaking. For the case of scribing and breaking, the scribing can be performed mechanically (e.g. using a diamond scribe tool). Alternatively, radiant energy (e.g. a laser) can be used to scribe the glass sheet. (Portions of the protective layer are typically burned away during laser scribing. During mechanical scribing or cutting, portions of the protective layer are typically cut. However, the protective layer remains on, and continues to protect, the portions of the glass workpieces that eventually serve as the major surfaces of the substrates being formed.)

In one embodiment, after laser scribing, the glass sheet is subjected to an acidic etching solution comprising fluoride ions. It has been discovered that this etching solution preferentially attacks the portions of the sheet that have been exposed

to the laser. Because of this, the edges of the workpiece are smoother and better defined than they would be using other scribing and breaking techniques.

In one embodiment, both sides of the glass sheet are scribed simultaneously. This also improves the definition of the edges of the resulting smaller workpieces.

After the above-mentioned cutting or scribing and breaking process, individual substrates are cut out of the smaller workpieces. This can be accomplished using any of the techniques described above for cutting the glass sheet into smaller workpieces. Of importance, the protective layer remains on the workpieces during this process, and continues to protect the workpieces from being scratched.

Thereafter, chamfers are formed on the substrates. This can be performed in several different ways. For example, in one embodiment, the chamfers are formed using a laser cutting technique.

In another embodiment, in lieu of forming chamfers, the corners of the substrate are rounded using an edge polishing technique. In one embodiment, this process is performed by applying an edge polishing material (e.g. a slurry containing CeO_2 or other glass polishing material) to the edge of the substrate. As explained below, this polishes the substrate edge and rounds the corners of the substrate.

In one embodiment, several substrates are stacked, and their edges are polished simultaneously. Of importance, the protective layer remains on both sides of each of the substrates, and continues to protect the substrates during this process. The protective layers on the substrates are softer than glass. The ID and OD of the stacked glass substrates are subjected to a polishing process, e.g. using a slurry. The portion of the protective layers at the ID and OD are removed first. This exposes portions of the glass substrates at the corner of the ID and OD to the slurry, and permits the slurry to round the substrate corners. It has been discovered it is not necessary to form

chamfers in a glass substrate, and that simply rounding the substrate corners suffices in a manufacturing process. In particular, the substrate can be safely handled, although it lacks chamfers, without damaging the substrate. Also, because the edges are rounded and not sharp, the substrates can be safely handled by people and associated process equipment. Further, by not chamfering the substrate corners, the expense and damage to the glass material associated with chamfering are avoided. The substrates are then destacked.

Although the edges of the substrate can be rounded while the substrates are stacked, e.g. by edge polishing, in other embodiments, the edges of one substrate at a time are rounded, e.g. by edge polishing.

It is at this point in the process of this embodiment that the protective layers are removed from the substrates. Of importance, because the protective layers have been on the substrates throughout the above-mentioned processing steps, the substrates are smooth and unscratched. Only minimal polishing (if any) is needed to put the substrates in condition for disk completion.

Optionally, the substrates can be subjected to a chemical strengthening step. After chemical strengthening, the substrates are again cleaned. The disks are typically completed by depositing, e.g. by sputtering, an underlayer, magnetic layer and protective overcoat, in that order, on the substrates. A lubricant layer is then applied to the protective overcoat.

In accordance with another aspect of the invention, after the substrates are cut out of the glass sheets, the substrates can be subjected to edge polishing without the presence of a protective layer on the substrate surfaces. In such a process, the substrates can be spaced apart from one another, e.g. using a set of spacers such as O-rings. The spacers do not typically contact the substrates at the data recording area of

the substrate. Rather, the spacers typically contact the substrate at the "clamp zone" of the substrate. (After completion of the substrate, a magnetic layer is typically deposited over the substrate surface. The data recording area is the area where data is subsequently recorded on the disk surface. The clamp zone is where the disk is clamped to a rotating spindle.) Because the spacers do not typically contact the data recording area, damage to the data recording area can be avoided. Edge polishing in accordance with the invention avoids much of the polishing and lapping normally applied to a prior art substrate. This is because prior art chamfering processes necessitated a great deal of lapping and polishing. By not chamfering the substrate, much of this lapping and polishing can be avoided.

After edge polishing, the substrates can be subjected to a polishing step. The substrates can then be subjected to chemical strengthening. The various layers of the magnetic disk can then be deposited on the substrates.

As mentioned above, edge polishing rounds the corners of the substrates. In one embodiment, the radius of curvature of the corners (at the inner diameter, the outer diameter, or both the inner and the outer diameter) is typically between 20 and 120 μm, and preferably 75 μm plus or minus 25 μm.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a magnetic disk comprising a glass substrate manufactured in accordance with the prior art.

Fig. 2 illustrates a process flow for manufacturing glass substrates in accordance with the prior art.

Fig. 3 illustrates in cross section a glass substrate in accordance with the prior art including chamfered edges.

Fig. 4 illustrates a process flow for manufacturing a glass substrate in accordance with the present invention.

Fig. 5 illustrates a glass sheet covered by protective layers.

Fig. 6 illustrates a glass substrate formed from the glass sheet of Fig. 5.

Fig. 7 illustrates a stack of substrates being subjected to edge polishing.

Fig. 8 is an expanded view of the stack of substrates of Fig. 7 being subjected to the edge polishing step, showing the manner in which the edges of the substrates are rounded during edge polishing.

Fig. 9 illustrates a disk drive comprising a disk manufactured using a method in accordance with the present invention.

Fig. 10 illustrates a stack of glass squares assembled during a manufacturing process in accordance with a second embodiment of the invention.

Fig. 11 illustrates a glass sheet being cut directly into substrates during a method in accordance with a third embodiment of the invention.

Fig. 12A illustrates a stack of substrates in cross section while their outer diameters are being subjected to edge polishing in accordance with one embodiment of the invention, wherein the substrates are separated from one another by a set of O-rings.

Fig. 12A' illustrates a stack of substrates in cross section while their outer diameters are subjected to edge polishing in accordance with another embodiment of the invention, wherein the substrates are separated from one another by a set of O-rings having a rectangular cross section.

Fig. 12B illustrates the stack of substrates of Fig. 12A in top plan view while their outer diameters are being subjected to edge polishing.

Fig. 12C illustrates the stack of substrates in cross section while their inner diameters are being subjected to edge polishing.

Fig. 12D illustrates the stack of substrates in top plan view while their inner diameters are being subjected to edge polishing.

DETAILED DESCRIPTION

I. First Embodiment

A method in accordance with the invention begins with the step of forming a glass sheet 100 (step A in Fig. 4). In one embodiment, glass sheet 100 (Fig. 5) is formed by the float method, but other techniques such as drawing can be used. As used herein, the term "drawing" includes down drawing, overflow fusion drawing (e.g. as described in U.S. Patent 3,338,696, issued to Dockerty), and similar processes. See also U.S. Patent 3,682,609, issued to Dockerty. (The '696 and '609 patents are incorporated herein by reference.) The glass is typically a silicate glass, e.g. aluminosilicate or borosilicate, but other types of glasses without additives or with different or additional additives, can be used as well.

Top and bottom surfaces 100a and 100b of glass sheet 100 are covered with protective layers 102a and 102b, respectively (step B of Fig. 4). In one embodiment, protective layers 102 are a water-soluble material such as latex. In another embodiment, layers 102 are a polymer that is not water-soluble. Of importance, protective layers 102 protect glass sheet 100 from being damaged during subsequent manufacturing processes. (In one embodiment, a protective layer is applied to only one side of glass sheet 100. This may be particularly practical for producing magnetic

disks having a magnetic layer on only one side of the substrate. Therefore, the quality of the other side of the substrate may not be very critical.)

Glass sheet 100 is then cut into individual workpieces 104 (step C). Workpieces 104 are typically square shaped, measuring 100 mm by 100 mm, and are typically 1 mm thick, but can be other shapes or sizes. Sheet 100 can be cut into workpieces 104 by sawing. Alternatively, sheet 100 can be cut into workpieces by scribing and breaking. Scribing can be accomplished by mechanically scribing sheet 100 using a diamond-scribing tool, laser scribing or laser scribing followed by etching (e.g. as discussed below). (Fig. 5 illustrates in phantom scribe lines 101 formed on glass sheet 100 during this scribing operation. Although Fig. 5 only shows sheet 100 as being five squares wide, sheet 100 can be many meters wide, and many tens of meters long. Thus, sheet 100 can contain many more squares 104 than are illustrated.) During diamond or laser scribing, protective layers 102 are typically cut by the diamond scribing tool or burned by the laser where the scribe line is being formed, but layers 102 otherwise remain intact during this process.

In one embodiment, glass sheet 100 is diamond or laser scribed on both sides of sheet 100. This results in improved edge profiles. (The reason for this is that scribing on both sides of sheet 100 causes a crack to propagate from the scribe line on one side of the glass sheet to the scribe line on the other side of the glass sheet. In other words, the two end-points of the crack are defined during scribing. The resulting crack is better defined than if there were a scribe line on only one side of sheet 100, and only one end-point of the crack were defined during scribing. This principle is illustrated in U.S. Patent Application 09/407,003, filed by Hsieh et al. on 9/28/99, incorporated herein by reference.) After diamond or laser scribing, glass sheet 100 is broken along the scribe lines into individual glass squares 104.

(Although both sides of sheet 100 are preferably scribed, in other embodiments, only one side of sheet 100 is scribed.)

After glass sheet 100 is formed into square workpieces 104, glass substrates 110 are cut out of the workpieces 104 (step D). This can be accomplished by sawing, mechanical scribing and breaking, or laser scribing and breaking. The substrates can have an outer diameter of about 95 mm, but other sizes can also be used (e.g. 25 to 95 mm). The inner diameter can be, for example, 10 to 25 mm.

In one embodiment using laser scribing, a laser beam (e.g. from a CO_2 laser) traces a scribe line on the workpiece, followed by application of a cold fluid (e.g. a cold gas or liquid) to the laser-scribed material and a subsequent etching step. See U.S. Patent Application Serial No. 09/407,630, filed September 28, 1999 by Hsieh et al., incorporated herein by reference. During this process, after laser scribing, sheet 100 is subjected to a fluoride containing acidic solution, e.g. hydrofluoric acid. Alternatively a solution of ammonium bifluoride and an acid such as H_2SO_4 can be used. One example of such a solution comprises 5 wt. % ammonium bifluoride, 5% by volume H_2SO_4 at room temperature, and a surfactant such as toluene sulfonic acid. (This material is sold as Eltesol TSX/A, manufactured by Albright & Wilson Corp.) Etching can be accomplished while the solution is ultrasonically agitated, e.g. at a frequency between 28 and 68 KHz. In one embodiment, the solution is agitated at 40 KHz. The '630 Application explains that the above-mentioned process provides smooth scribe mark structures that are particularly advantageous for providing precise definition during scribing and breaking.

As can be seen in Fig. 6, substrates 110 are disk-shaped, and have an inner circular hole 111 formed therein. Hole 111 is typically formed by scribing and breaking as described above. As described below, hole 111 is used to mount the

completed disk onto a spindle in a disk drive. Fig. 6 also shows that a portion of protective layers 102a, 102b remains on the top and bottom surfaces of substrate 110 at this point in the manufacturing process. Thus, protective layers 102a, 102b continue to protect the major surfaces of substrate 110.

Glass substrates 110 may then be subjected to an edge polishing technique (step E of Fig. 4). In one embodiment of this process, substrates 110 are stacked, e.g. as shown in Fig. 7. One advantage of using a sheet of material as a protective layer is that the thickness of the sheet is generally well controlled. By having a repeatable amount of space between all workpieces, in a given stack and from stack to stack, the edge profile is well controlled and repeatable.

Optionally, substrates 110 can be bonded with an adhesive during stacking. The adhesive can be the protective layer. In embodiments where the adhesive functions as a protective layer, it preferably comprises at least a component that is substantially solid or highly viscous prior to stacking substrates 110. This component prevents glass splinters that may be present from moving against and thereby scratching the major surface of substrates 110. The adhesive-coated substrates can be bonded together by e.g. a) heat-fusing the adhesive layers on the various substrates; b) using a sufficiently viscous adhesive so as to prevent excessive movement of any particles that may be present; or c) applying a solvent that temporarily liquefies a surface portion of the adhesive coating on the substrate to thereby bond the adhesive coatings on the substrate. This is particularly useful during coring operations (described below) where significant forces act on the workpieces, which would otherwise cause the individual workpieces to move with respect to one another. If an adhesive is used during edge polishing, it is desirable that the adhesive can be placed between the workpieces with consistent thickness for the reasons discussed above.

The edges of substrates 110 are then subjected to a chemical mechanical polishing ("CMP") process. During this process, a polishing slurry, e.g. a slurry comprising particles such as CeO_2, is applied to the stack. The slurry can also comprise additives and surfactants. Alternatively, polishing agents other than CeO_2 can be used. (In one embodiment, mechanical polishing is used, and the slurry can include abrasive polishing particles such as alumina, silica, diamond, or other polishing particles.) The slurry can be applied to the substrates using a polishing pad 120. (The slurry is typically introduced between pad 120 and stack 122.) This has two major advantages:

1. It removes damaged glass material at the disk OD. (This includes glass material damaged by cutting or scribing and breaking the glass.)
2. This polishing step rounds the edges of substrates 110.

The reason that the substrate edges are rounded can be understood by referring to Fig. 8. Referring to Fig. 8, roughly cylindrical polishing pad 120 polishes the OD of stack 122 of substrates 110. As can be seen, stack 122 comprises glass substrates 110 and protective layers 102. Protective layers 102 are typically made of softer material than substrates 110, and therefore wear more rapidly than substrates 110 in response to the polishing. As protective layers 102 wear, they expose the outer portions of the top and bottom surfaces of substrates 110 to the polishing slurry, thereby permitting the polishing slurry to polish the exposed portions and round the edges of the corners of substrates 110.

In Fig. 7 and 8, one polishing pad is shown polishing the OD of stack 120 of substrates 110. However, in other embodiments, two or more pads can be used to simultaneously polish the OD of the stack. During this process, stack 120 can be rotated, e.g. in the direction of arrow A. Alternatively, the pads can rotate around

stack 120. In addition, pad 122 can rotate about its central axis in the direction of arrow B.

Either before, after, or concurrently with the polishing of the OD of substrates 110, the ID of substrates 110 is subjected to a similar polishing process, using an elongated polishing pad (not shown), thereby rounding the corners of substrates 110 at their ID.

In this embodiment, the corners of substrates 110 are rounded, and not chamfered. Substrates having rounded corners function just as well as substrates with chamfered edges.

While Figs. 7 and 8 show a stack of substrates 110 having their edges polished simultaneously, in another embodiment, the edges of substrates 110 are polished one at a time.

After polishing, substrates 110 are destacked, and the protective layers 102 are removed (step F). (As mentioned above, in one embodiment the material of layers 102 is water soluble, and layers 102 are removed with water.) Substrates 110 are then subjected to a minimal polishing step and cleaned (step G). This polishing step is designed to eliminate "waviness". Waviness is a high wavelength surface imperfection, e.g. a variation in flatness having a wavelength greater than the size of the read-write head used with the disk, e.g. a wavelength on the order of a few millimeters to 1 cm. See U.S. Patent Application 09/262,365, filed March 4, 1999 by Bajorek et al., incorporated herein by reference.

The minimal polishing step described above should not be confused with other prior art grinding, lapping and polishing steps used to remove damage caused during chamfering, cutting, stacking and destacking. (Grinding is an extremely aggressive process, typically involving a grinding stone. Lapping refers to an aggressive form of

polishing, with either a free or fixed abrasive, which results in high material removal but creates an unacceptably rough surface finish. Polishing refers to a very fine form of material removal, typically with a free abrasive, that results in a very smooth surface finish.) During these prior art grinding, lapping and polishing steps, it is necessary to remove between 250 and 1000 μm of glass. In contrast, the above-described minimal polishing step typically removes less than about 100 μm and in one embodiment about 5 μm of glass or less. Thus, the polishing performed in the present invention is much less expensive than the grinding, lapping and polishing done in prior art processing steps.

A minimal polishing step, as described above, does not substantially disturb the short wavelength smoothness of the original glass sheet (e.g. having a Ra of about 1.5 Å). (Although the as-formed glass sheet produced by the float method has a low Ra, because the prior art processes damage the glass, the glass must be substantially polished to remove the damaged material and recreate a smooth surface. Because damage of the glass during manufacturing is avoided or reduced in the present invention, the initial smoothness of the glass is retained, and it is not necessary to subject substrates 110 to extensive polishing and lapping to recreate the initial smoothness.)

While the minimal polishing step is performed in one embodiment of the invention, in another embodiment, the minimal polishing step is not performed.

Optionally, at this point glass substrates 110 are subjected to chemical strengthening (step H). As is well known in the art, chemical strengthening is performed on Na-containing glass. During chemical strengthening, the substrates are immersed in a bath of a molten potassium (K) salt. Na ions diffuse out of the glass, while K ions diffuse into the glass. Since K ions have a greater diameter than Na

ions, the K ions form a compression region adjacent the substrate surface, which prevents the propagation of cracks through the substrate, and results in a stronger substrate. After chemical strengthening, the glass substrate is cleaned.

Thereafter, substrates 110 are used to manufacture magnetic disks. This is typically accomplished by depositing an underlayer (e.g. Cr, a Cr alloy, NiAl, or NiP); a magnetic Co alloy; and a protective layer (e.g. carbon) onto the glass substrate. Deposition is typically accomplished by sputtering (step K). (More than one underlayer, magnetic layer and protective overcoat can be formed on the substrate during this part of the process.) Details concerning one manufacturing process that can be used are set forth in U.S. Patent Application 08/894,753, filed by Bertero et al. on December 4, 1997, incorporated herein by reference.

After the substrates are used to manufacture magnetic disks, the disks are provided in magnetic hard disk drives, e.g. disk drive 200 schematically shown in Fig. 9. Referring to Fig. 9, disk drive 200 comprises a magnetic disk 202 formed using a manufacturing process in accordance with the invention. Read-write heads 204a, 204b are held in proximity to top and bottom surfaces 202a, 202b of magnetic disk 202, respectively, by suspension arms 206a, 206b. Arms 206a, 206b are mounted on an actuator 208 so that heads 204 can be moved relative to disk 202, and so that heads 204 can access different tracks on disk 202.

Disk 202 is mounted on a spindle 210, which in turn is coupled to a motor 212 for rotating disk 202. During use, disk 202 is rotated, and heads 204a, 204b "fly" over an air cushion that forms in response to the rotation of disk 202.

II. Second Embodiment

In another embodiment of the invention, prior to cutting glass squares 104 into substrates, squares 104 are stacked to form stack 300 (Fig. 10). Squares 104 are optionally bonded together with an adhesive during stacking. Thus, a stack of glass squares can be processed simultaneously to minimize costs. (The adhesive used to bond squares 104 together can be the protective layer, e.g. protective layer 102. As in the embodiment discussed above, the adhesive that functions as a protective layer typically is designed to prevent damage due to the presence of particles between the workpieces. As mentioned above, use of an adhesive is particularly advantageous in this context.)

Next, the glass squares are subjected to a boring process during which a circular hole 302 (shown in phantom in Fig. 10) is drilled or bored through bonded squares 104. Hole 302 constitutes the ID of the glass substrates being manufactured. A second cutting tool cuts a circular section 304 (also shown in phantom in Fig. 10) out of stack 300 of glass squares 104. This circular section 304 constitutes a stack 122 of glass disk-shaped substrates 110 being manufactured. The drilling and cutting tools used during this part of the process are conventional.

Thereafter, stack 122 of glass substrates 110 are subjected to edge polishing as discussed above. After edge polishing, the substrates are destacked, and processing continues as discussed above. Of importance, protective layers 102 protect substrates 110 during stacking, cutting, edge polishing and destacking.

III. Third Embodiment

Referring to Fig. 11, glass sheet 100 is covered with protective layers 102. Instead of cutting sheet 100 into squares, and then cutting substrates out of the squares, glass substrates are cut directly out of glass sheet 100. This can be

accomplished by sawing or scribing and breaking. In one embodiment, one or more laser beams traces out circular paths on glass sheet 100 to thereby scribe glass sheet 100 (see Fig. 11). (As in the previous embodiments, portions of protective layers 102 are burned through by the laser beams during this process step.) In another embodiment, one or more mechanical cutting tools, e.g. diamond scribing tools, scribe a set of circular regions of sheet 100. (The laser beams or scribing tools are schematically shown in Fig. 11 as 106.) These scribe lines, which define both the inner and outer diameters of the substrates, are shown in phantom in Fig. 11 as lines 105. Typically, a row of scribe lines are formed by scribing tools 106, sheet 100 is moved in direction D, and then another row of scribe lines are formed in sheet 100. (Although Fig. 11 shows only four sets of scribe lines formed in a row in sheet 100, in some embodiments, sheet 100 is many meters wide, and many sets of scribe lines are formed simultaneously in a row on sheet 100.)

In yet another embodiment, instead of using scribing tools or laser beams, a plurality of saws cut a plurality of circular regions of sheet 100. In either event, in this embodiment circular substrates are cut out of sheet 100 without first cutting the sheet into square workpieces 104.

For the case of scribing, both sides of glass sheet 100 can be scribed (either using a laser or mechanical scribing) to ensure well-defined substrate edges, e.g. as described in above-incorporated U.S. Patent Application 09/407,003. Also, for the case of laser scribing, glass sheet 100 can be subjected to an acidic solution comprising fluoride ions as described in above-incorporated U.S. Patent Application 09/407,630. Sheet 100 is then subjected to a breaking operation to form substrates 110.

After sheet 100 is cut into individual substrates 110, processing proceeds as discussed above. In other words, the substrates are stacked and subjected to edge polishing. The substrates are then destacked and processed as described above.

IV. Fourth Embodiment

Edge polishing can be performed without necessarily having a protective layer on substrates 110. For example, referring to Figs. 12A and 12B, substrates 110 within stack 200 can be separated from one another by spacers such as O-rings 202. Because of this, there will be a space 204 between substrates 110. Stack 200 is mounted on a spindle 206, which rotates substrates 110 in the direction of arrow C. (Spindle 206 is typically coupled to a motor.) Concurrently, a cylindrical, soft polishing pad 208 polishes the outer edge of substrates 110 to round the corners of substrates 110. Pad 208 typically rotates in the direction of arrow D. (Pad 208 is also typically coupled to a motor for rotating pad 208). Optionally, concurrently, pad 208 can be moved up and down, e.g. as represented by arrow E. A slurry can be introduced between the polishing pad and the substrates. As mentioned above, this slurry can be a ceria slurry dispersed in an aqueous medium. Such a slurry can be formed using Mirek E-30, available from Mitsui Corporation of Japan. Mirek E-30 comes in the form of a powder that can be mixed with water (and optionally, one or more surfactants) to form a slurry. The ceria concentration within the slurry can be 5 to 20% by weight. Alternatively, a silica, alumina or diamond slurry can be used.

After polishing the outer edge of substrates 110, as shown in Fig. 13A and 13B, the inner edge of substrates 110 is polished, e.g. using a polishing pad 210. During this step, pad 210 rotates, e.g. in the direction of arrow F. Concurrently, substrates 110 rotate in the direction of arrow G. (Rotational force can be applied to

substrates 110 via their outer edges during this portion of the process.) During this process, pad 210 can be moved up and down.

Preferably, O-rings 202 only contact substrates 110 outside the data recording area of the substrates at the substrate inner diameter. For example, the contact area between O-rings 202 and substrates 110 can be confined to the an area within 1 or 2 mm of the inner diameter of the substrates.

Merely by way of example, O-rings 202 can be viton, nitrile, buta-N, Teflon (PTFE), silicone or other appropriate material. O-rings can space substrates 110 apart from one another by a distance between 0.5 and 3 mm. Pads 208 and 210 can be poromeric polyurethane, e.g. available from Mipox Corp. of Japan or Rodel Corp. of Delaware. The rotational velocity of pads 208, 210 and substrates 110 can be between 10 and 2500 rpm during polishing. Pads 208 and 210 can move up and down at a frequency between 0 and 100 strokes per second, at a stroke distance between 0 and 25 mm.

The radius of curvature of the substrate corners can be between 20 and 120 μm, and preferably 50 to 100 μm. This can be accomplished with a polishing time of about 30 minutes for the outer edge of substrates 110, and a polishing time of 10 minutes for the inner edge, depending upon such parameters as the contact pressure between the pad and the substrates.

Although O-rings 202 are used to space substrates 110 apart to enable the polishing pads to access and round the corners of the substrates, in another embodiment, another means (e.g. spacers having other shapes) can be used to space the substrates apart from one another. For example, instead of using O-rings 202 which have a circular cross-section, in other embodiments, rings can be used that have a square, rectangular or other shaped cross section. For example, as shown in Fig.

12A', rings 202' can be used having a square cross section. Alternatively, any shaped spacer can be used to separate substrates 110 from one another. Moreover, the spacers need not have a continuous or closed shape. One or more inserts or pieces of material disposed between the disks by any means may be used as a spacer. As a further exemplary embodiment, the disks may be held at one or more points along the OD or ID edge or for a distance along such edges (similar to the manner in which the slots of a cassette hold the disks). In the foregoing embodiment, while one of the ID or OD is held in such manner, the other of the OD or ID can be polished as described herein. In general, any means of creating a spacing between sequential ones of the diameter being treated may be employed. However, again, it is preferred (but not necessary in all embodiments) that these spacers not extend into the data recording area of substrates 110.

While the invention has been described with respect to specific embodiments, those skilled in the art will appreciate that changes can be made in form and detail without departing from the spirit and scope of the invention. For example, different techniques can be used to cut or break glass to form substrates. In addition, different types of materials other than glass-containing materials such as ceramic or other materials can be used in this invention. In lieu of the float method, different substrate manufacturing techniques can be used. In some embodiments, portions of the sheet of glass at its periphery are cut away and disposed of, rather than being used to manufacture substrates. Thus, substrates are not formed from the glass at the very edge of the glass sheet (e.g. if the edge of the glass sheet is poorer quality material). Any layer present on the substrate surface during edge polishing need not extend all of the way to the inner and outer edge of the substrates. The substrate can have inner and outer diameters and thicknesses other than as set forth above. For example, the

substrates can have a thickness between 0.4 and 1.3 mm. It should also be noted that different aspects and features of one embodiment of the invention described above can be practiced either independently or in combination with different aspects of the other embodiments described above. Accordingly, all such changes come within the invention.

I claim:

1. Method for manufacturing a magnetic disk substrate, said method comprising the act of rounding the corners of said substrate.

2. Method of claim 1 wherein said substrate has unchamfered corners.

3. Method of claim 1 wherein after said rounding of said corners, said corners have a radius of curvature between about 20 and 120 μm.

4. Method of claim 1 further comprising forming a magnetic layer over said substrate.

5. Method of claim 4 further comprising providing an underlayer between said substrate and said magnetic layer.

6. Method of claim 1 further comprising providing a stack of substrates, said substrates having unchamfered outer edges, said rounding comprising polishing the unchamfered edges of said stack of substrates, whereby during said polishing, the corners of said stack of substrates are rounded, said method further comprising:

unstacking said stack of substrates; and

forming a magnetic layer over said substrates.

7. Method of claim 6 wherein said substrates have unchamfered inner edges, said method also comprising polishing said unchamfered inner edges of said substrates to round the corners of said inner edges.

8. Method of claim 6 or 7 wherein a layer of material is provided between said substrates within said stack, said layer of material eroding more rapidly during polishing than the substrate material, and wherein a portion of the major surfaces of said substrates are exposed when said layer of material erodes, thereby exposing said portion of said major surface and causing said edges to be rounded during polishing.

9. Method of claim 6, 7 or 8 further comprising providing a underlayer between said substrate and said magnetic layer and a protective overcoat over said magnetic layer.

10. Method of claim 6 or 7 wherein a spacer is provided to separate said substrates from one another during edge polishing.

11. Method of claim 10 wherein said spacer is an ring.

12. A magnetic disk manufactured by the method of claim 1.

13. A magnetic disk comprising a substrate, said substrate comprising unchamfered rounded outer edges, said magnetic disk further comprising a magnetic layer over said substrate.

14. Magnetic disk of claim 13 wherein said substrate is made from glass or glass ceramic.

15. Magnetic disk of claim 13 wherein said rounded outer edges have corners having a radius of curvature between 20 and 120 μm.

16. Magnetic disk of claim 13 or 14 further comprising an underlayer between said substrate and said magnetic layer, said disk also comprising a protective overcoat over said magnetic layer.

17. A method for manufacturing a substrate comprising:

applying a protective overcoat over a sheet of material;

cutting the sheet of material into disk-shaped substrates after applying said protective overcoat; and

removing the protective overcoat after said cutting of the sheet of material into disk-shaped substrates.

18. Method of claim 17 wherein said cutting of the sheet of material into disk-shaped substrates comprises:

cutting the sheet of material into workpieces after applying said protective overcoat; and

cutting the workpieces into disk-shaped substrates.

19. Method of claim 17 or 18 wherein said protective overcoat is applied to both sides of said sheet of material.

20. Method of claim 17 or 18 wherein said protective overcoat is applied to only one side of said sheet of material.

21. Method of claims 17, 18, 19 or 20 further comprising subjecting said substrates to edge polishing, said edge polishing resulting in rounded corners of the substrates, said protective overcoat remaining on said substrates during said edge polishing.

22. Method of claim 17, 18, 19 or 20 further comprising forming chamfers on the edges of said substrates.

23. Method of claim 17, 18, 19, 20 or 21 wherein said sheet of material comprises glass or glass ceramic.

24. Method of claim 17, 18, 19, 20, 21, 22, or 23 further comprising depositing a magnetic layer over said substrate.

25. Method of claim 24 further comprising forming an underlayer between said substrate and said magnetic layer and forming an overcoat over said magnetic layer.

26. Method of claim 19 wherein said cutting of said workpieces into disk-shaped substrates comprises:

stacking said workpieces;

cutting a central core through said stack to form the inner diameter of said substrates; and

cutting away an outer wastepiece from said stack to thereby form the outer diameter of said substrates, said protective layer remaining on said workpieces during said stacking, cutting a central core, and cutting away said outer wastepiece.

27. Method comprising:

applying a protective layer to a workpiece prior to performing a step in which the workpiece surface would otherwise be subjected to mechanical damage;

subjecting the workpiece to a process step during which the protective layer protects the workpiece from mechanical damage;

removing the protective layer; and

wherein at the end of said method, said workpiece is formed into a substrate for a magnetic disk.

28. Method of claim 27 wherein said process comprises scribing and breaking.

29. Method of claim 27 wherein said process step comprises stacking and destacking.

30. Method of claim 29 wherein the process step comprises transporting the workpiece from one operation station to another operation station.

31. Method of claim 29 further comprising forming a magnetic layer on said substrate.

32. Method of claim 31 further comprising forming an underlayer between said substrate and said magnetic layer and forming a protective overcoat over said magnetic layer.

33. Method of claim 27 further comprising:

applying a second protective layer to the workpiece;

subjecting the workpiece to a process step during which the protective layer protects the workpiece from mechanical damage; and

removing the second protective layer.

34. Method of claim 10 wherein said spacer is a protective layer.

35. Method comprising:

applying a protective layer to a workpiece prior to performing a step in which the workpiece surface would otherwise be subjected to risk of mechanical damage;

subjecting the workpiece to a process step during which the protective layer protects the workpiece;

removing the protective layer; and

wherein at the end of said method, said workpiece is formed into a substrate for a magnetic disk.

AMENDED CLAIMS

[received by the International Bureau on 25 December 2000 (25.12.00); original claims 1-35 replaced by new claims 1-28 (5 pages)]

1. Method for manufacturing an unchamfered magnetic disk substrate, said method comprising the act of rounding at least one of the corners of said substrate, said substrate being unchamfered prior to or during said rounding.

2. Method of claim 1 wherein after said rounding of said corners, said corners have a radius of curvature between about 20 and 120 µm.

3. Method of claim 1 further comprising forming a magnetic layer over said substrate.

4. Method of claim 3 further comprising providing an underlayer between said substrate and said magnetic layer.

5. Method of claim 1 further comprising providing a stack of substrates, said substrates having unchamfered outer edges, said rounding comprising polishing the unchamfered edges of said stack of substrates, whereby during said polishing, the outer corners of said stack of substrates are rounded, said method further comprising:

unstacking said stack of substrates; and

forming a magnetic layer over said substrates.

6. Method of claim 5 wherein said substrates have unchamfered inner edges, said method also comprising polishing said unchamfered inner edges of said substrates to round the corners of said inner edges.

7. Method of claim 5 or 6 wherein a layer of material is provided between said substrates within said stack, said layer of material eroding more rapidly during polishing than the substrate material, and wherein a portion of the major surfaces of said substrates are exposed when said layer of material erodes, thereby exposing said portion of said major surface and causing said edges to be rounded during polishing.

8. Method of claim 5, 6 or 7 further comprising providing an underlayer between said substrate and said magnetic layer and a protective overcoat over said magnetic layer.

9. Method of claim 5 or 6 wherein a spacer is provided to separate said substrates from one another during edge polishing.

10. Method of claim 9 wherein said spacer is a ring.

11. Method of claim 10 wherein said spacer is a protective layer.

12. A magnetic disk manufactured by the method of claim 1.

13. A magnetic disk comprising a substrate, said substrate comprising top and bottom major surfaces, inner and outer edge surfaces, and corners between said major surfaces and said edge surfaces, said corners being unchamfered, at least one of said

corners being rounded, said magnetic disk further comprising a magne~~tic layer over~~ said substrate.

14. Magnetic disk of claim 13 wherein said substrate is made from glass or glass ceramic.

15. Magnetic disk of claim 13 wherein said rounded corners have a radius of curvature between 20 and 120 μm.

16. Magnetic disk of claim 13, 14, or 15 further comprising an underlayer between said substrate and said magnetic layer, said disk also comprising a protective overcoat over said magnetic layer.

17. A method for manufacturing a substrate comprising:

applying a protective overcoat over a sheet of material;

cutting the sheet of material into disk-shaped substrates after applying said protective overcoat;

subjecting said substrates to edge polishing, said edge polishing resulting in rounded corners of the substrates, said protective overcoat remaining on said substrates during said edge polishing; and

removing the protective overcoat after said cutting of the sheet of material into disk-shaped substrates and after said edge polishing.

18. Method of claim 17 wherein said cutting of the sheet of material ~~into disk-~~ shaped substrates comprises:

cutting the sheet of material into workpieces after applying said protective overcoat; and

cutting the workpieces into disk-shaped substrates.

19. Method of claim 17 or 18 wherein said protective overcoat is applied to both sides of said sheet of material.

20. Method of claim 17 or 18 wherein said protective overcoat is applied to only one side of said sheet of material.

21. Method of claim 17, 18, 19 or 20 wherein said sheet of material comprises glass or glass ceramic.

22. Method of claim 17, 18, 19 or 20 further comprising depositing a magnetic layer over said substrate.

23. Method of claim 22 further comprising forming an underlayer between said substrate and said magnetic layer and forming an overcoat over said magnetic layer.

24. Method of claim 22 wherein said cutting of said workpieces into disk-shaped substrates comprises:

stacking said workpieces;

cutting a central core through said stack to form the inner diameter of said substrates; and

cutting away an outer wastepiece from said stack to thereby form the outer diameter of said substrates, said protective layer remaining on said workpieces during said stacking, cutting a central core, and cutting away said outer wastepiece.

25. Method for manufacturing a magnetic disk substrate, said disk substrate having first and second major surfaces, an outer edge surface circumferentially surrounding said substrate, an inner edge surface, inner corners between said major surfaces and said inner edge surface, and outer corners between said major surfaces and outer edge surface, said method comprising rounding at least one of said corners such that at the conclusion of said method, said substrate has a rounded corner that separates one of said major surfaces and one of said inner or outer edge surfaces.

26. Method of claim 25 further comprising rounding both said inner and outer corners whereby at the end of said method, said substrate comprises upper and lower rounded corners between said major surfaces and said inner edge surface and upper and lower rounded corners between said major surfaces and said outer edge surface.

27. Method of claim 25 and 26 wherein said substrate is unchamfered.

28. Method of claim 25, 26 and 27 wherein the radius of curvature of the rounded corners is between about 20 and 120 μm.

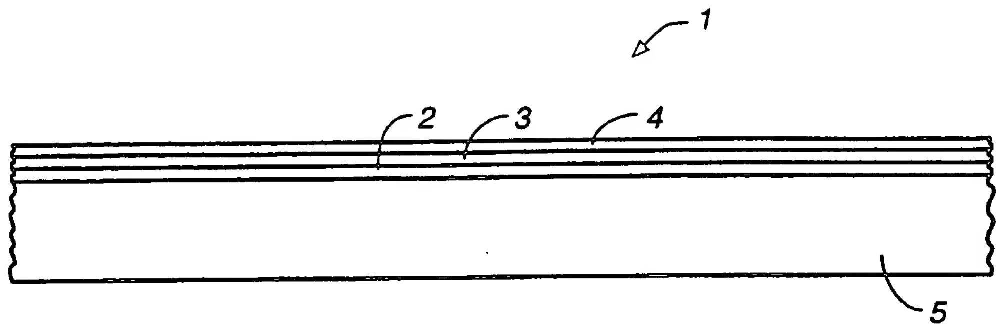

FIG._1 (PRIOR ART)

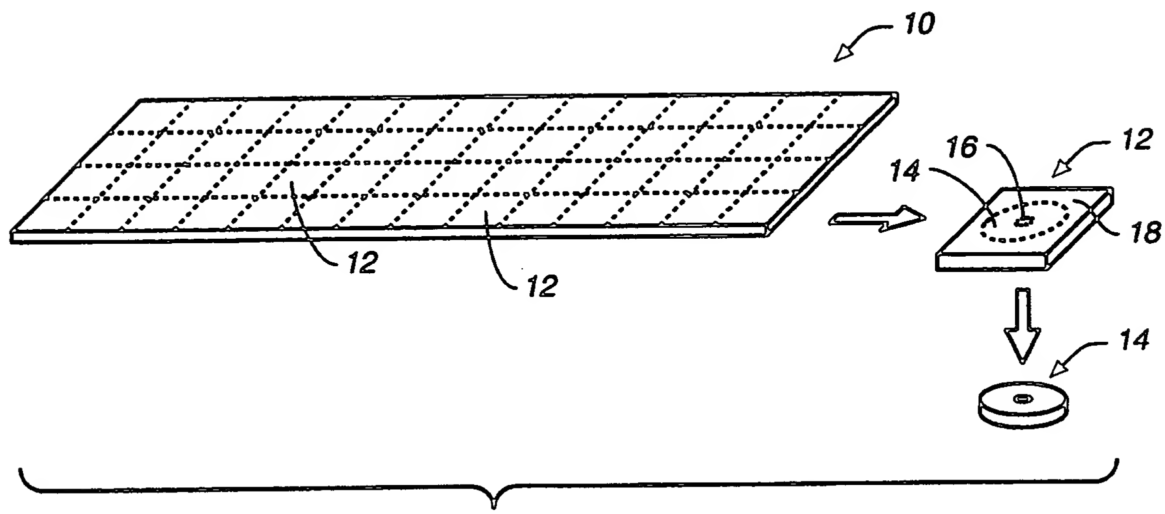

FIG._2 (PRIOR ART)

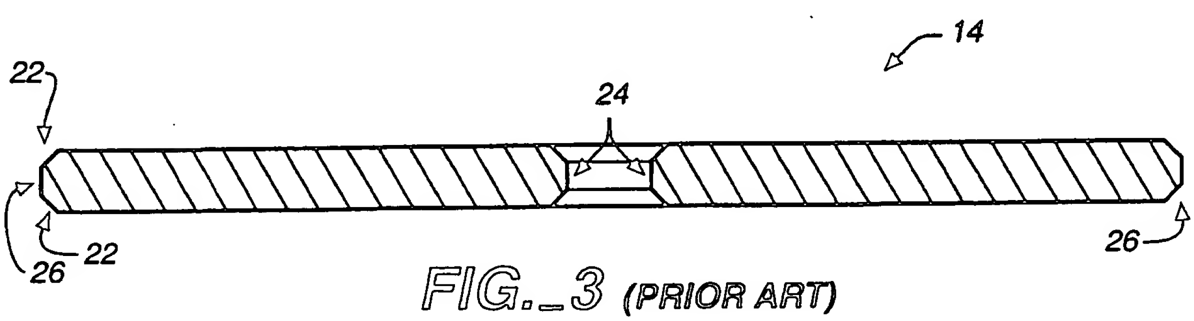

FIG._3 (PRIOR ART)

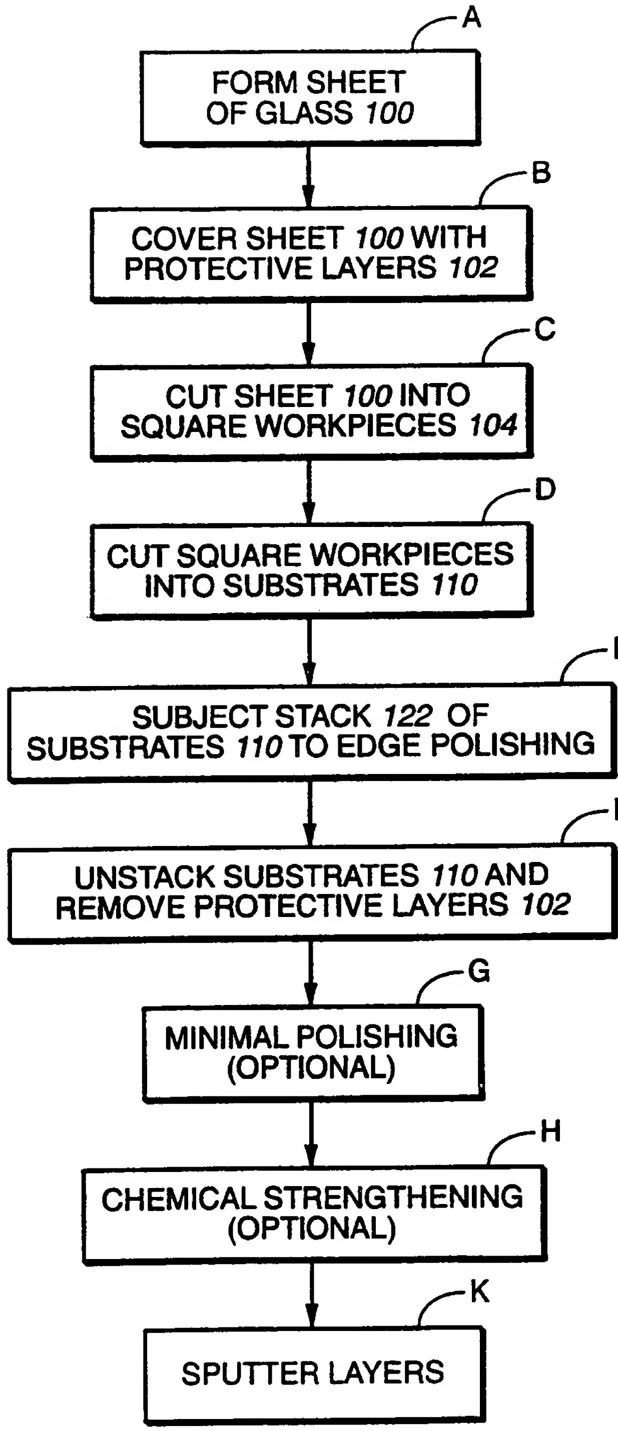
A
FORM SHEET OF GLASS 100
B
COVER SHEET 100 WITH PROTECTIVE LAYERS 102
C
CUT SHEET 100 INTO SQUARE WORKPIECES 104
D
CUT SQUARE WORKPIECES INTO SUBSTRATES 110
E
SUBJECT STACK 122 OF SUBSTRATES 110 TO EDGE POLISHING
F
UNSTACK SUBSTRATES 110 AND REMOVE PROTECTIVE LAYERS 102
G
MINIMAL POLISHING (OPTIONAL)
H
CHEMICAL STRENGTHENING (OPTIONAL)
K
SPUTTER LAYERS

FIG._4

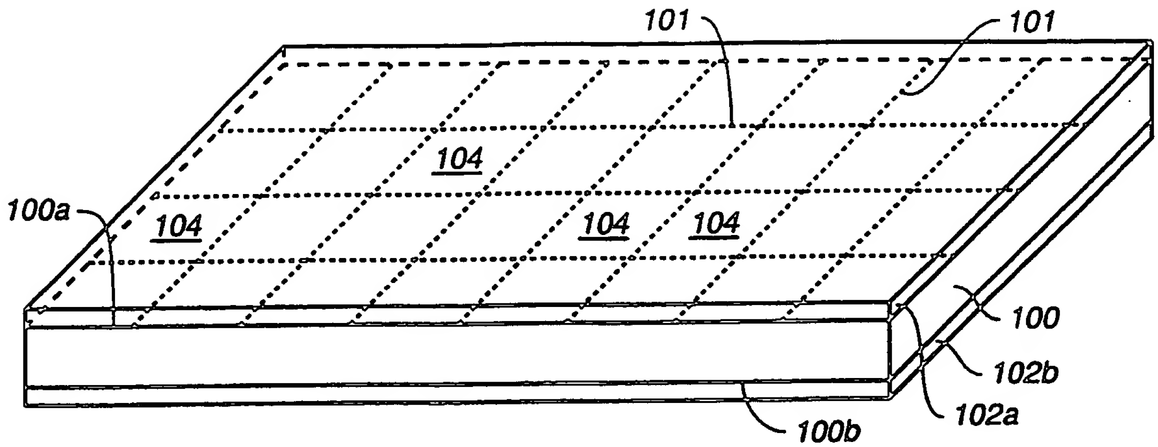

FIG._5

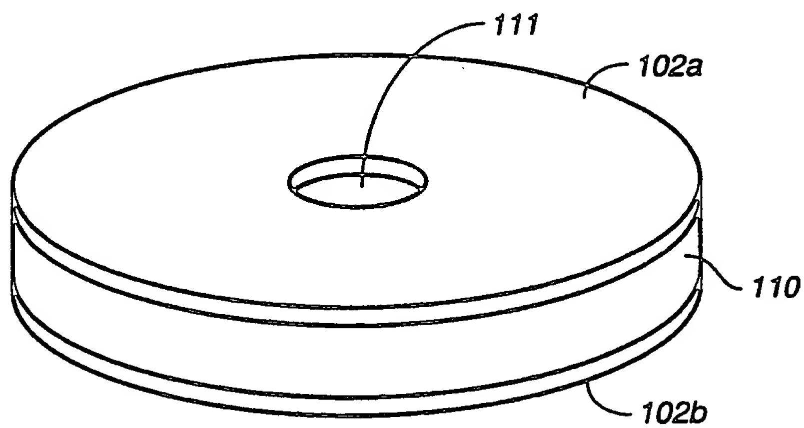

FIG._6

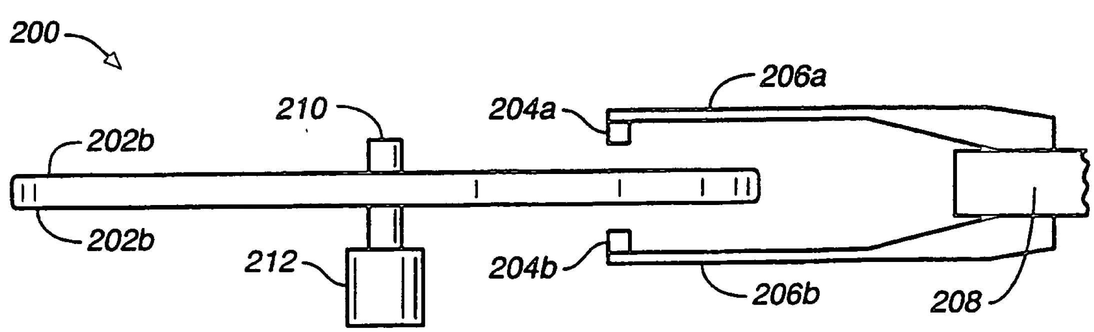

FIG._9

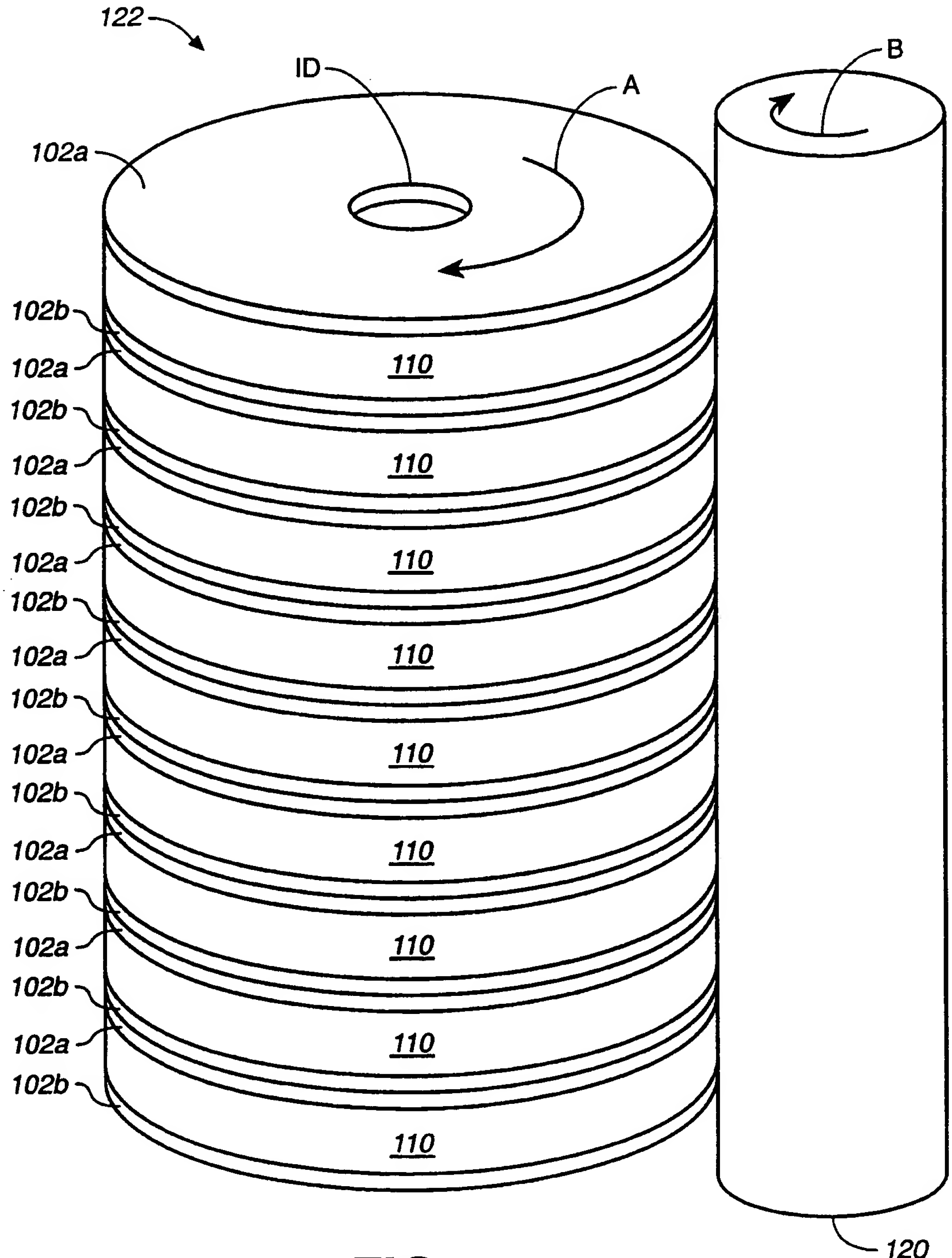
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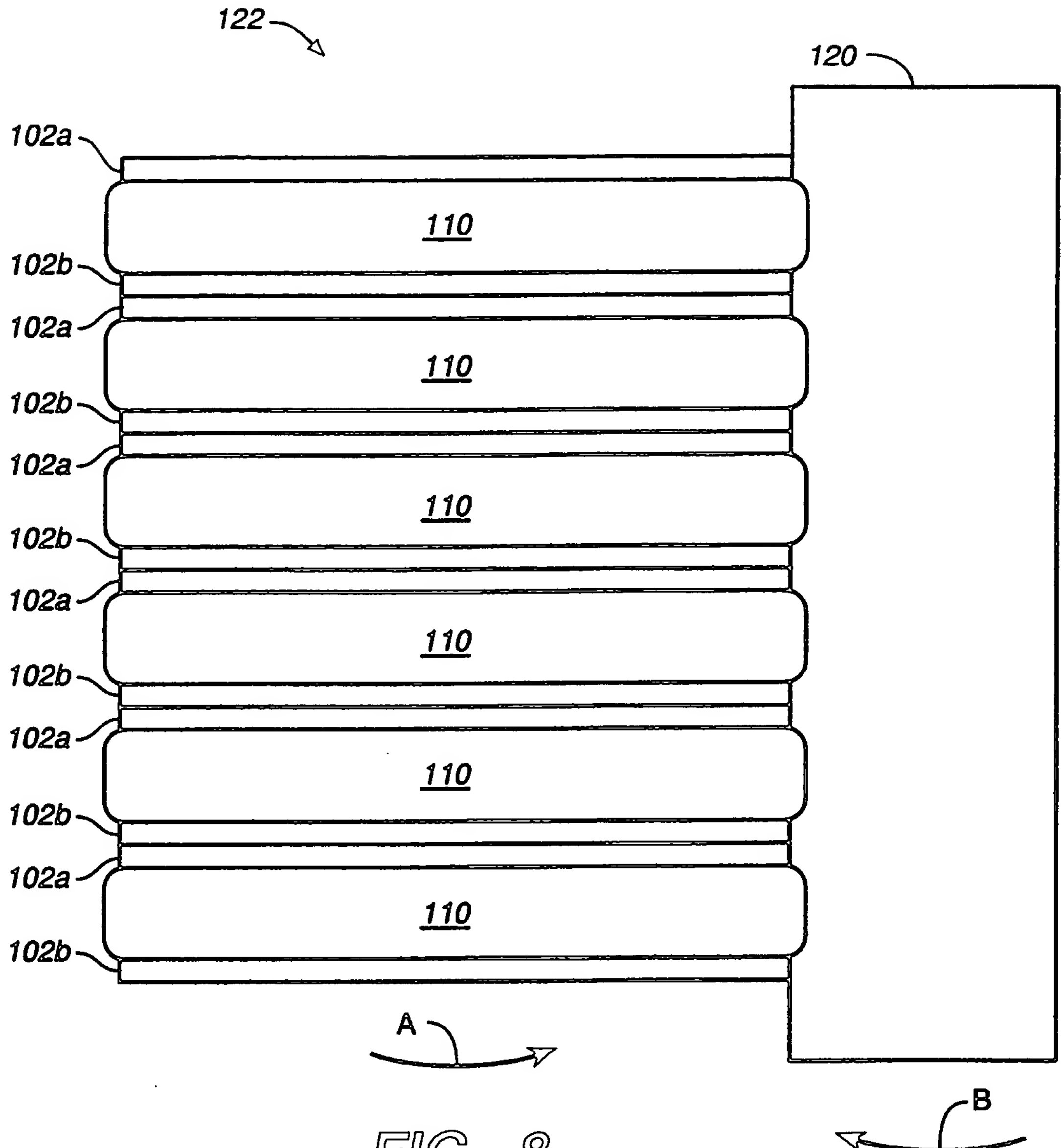
FIG._7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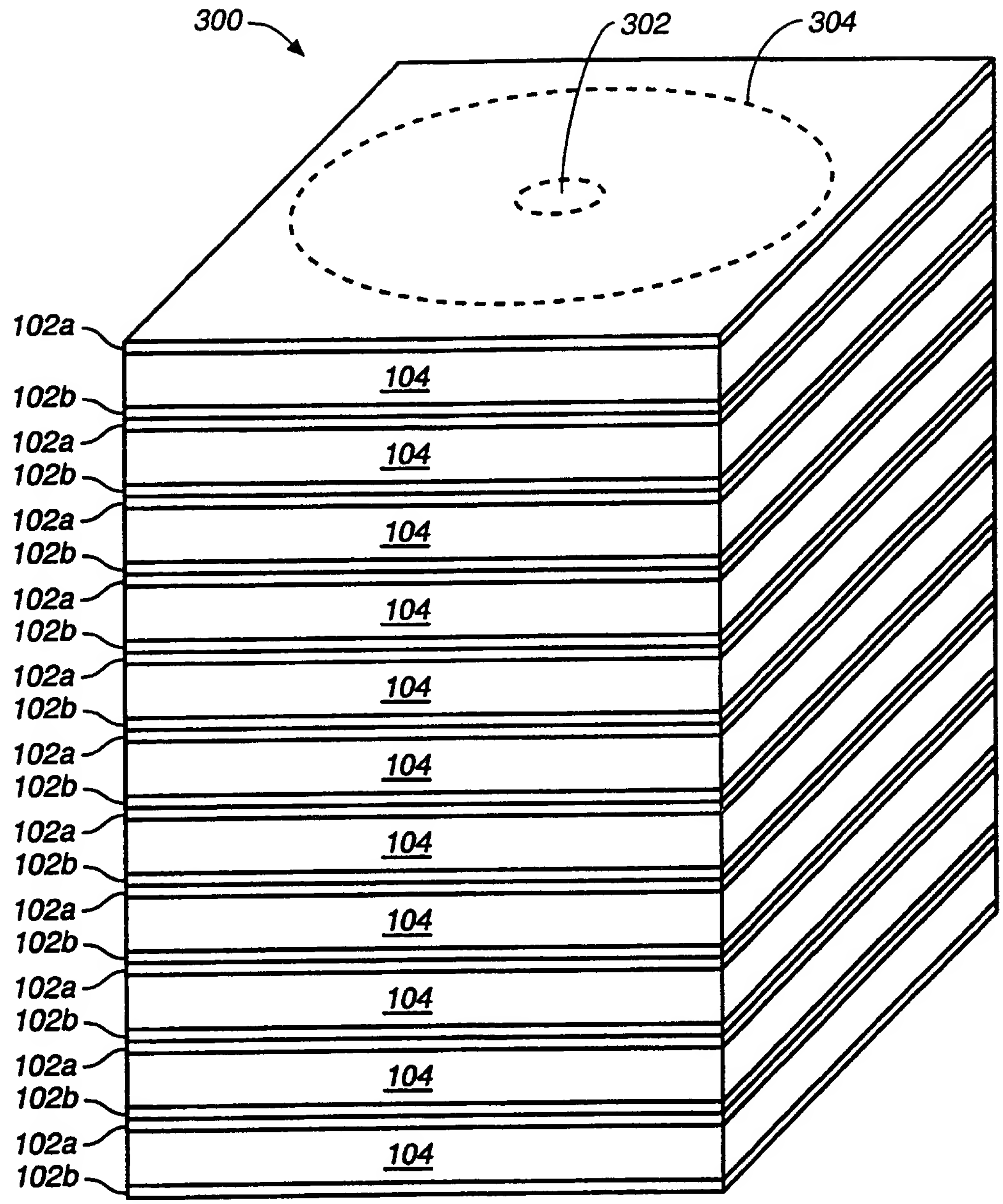
B

FIG._8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102b
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102a
104
102b

FIG._10

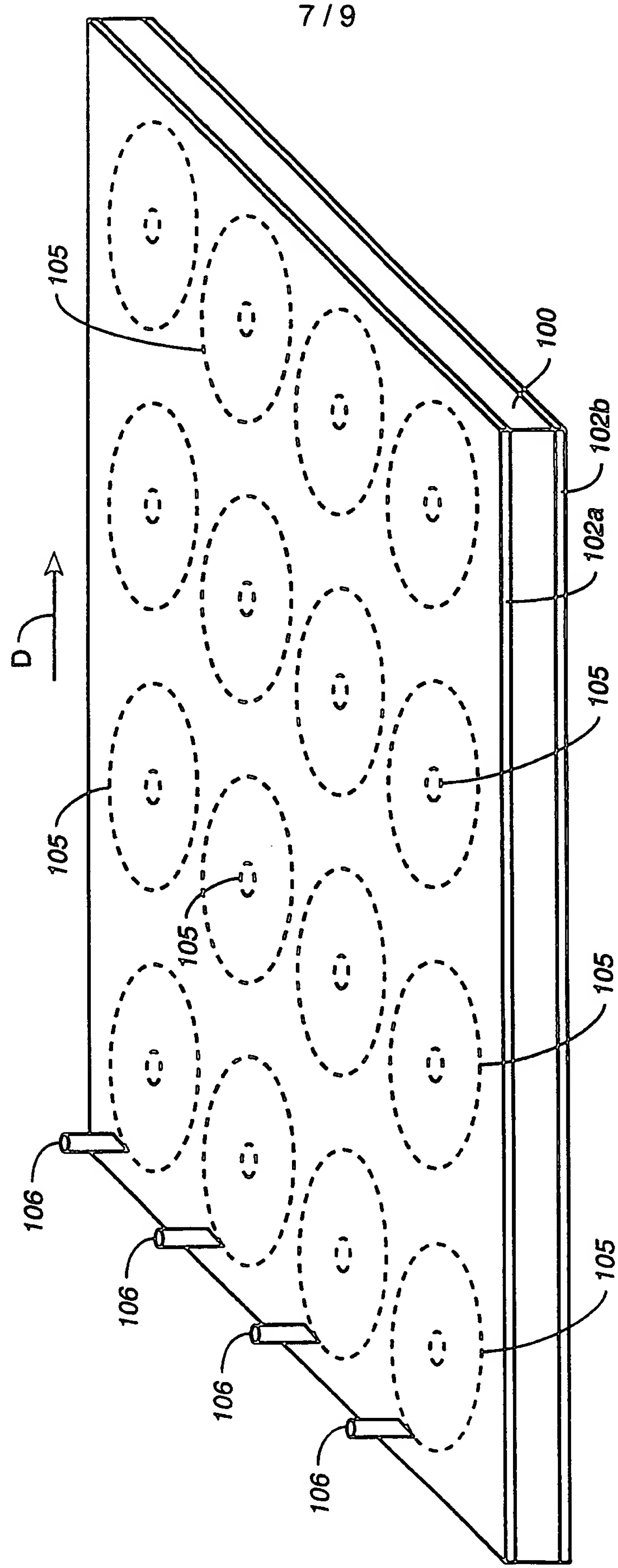

FIG._11

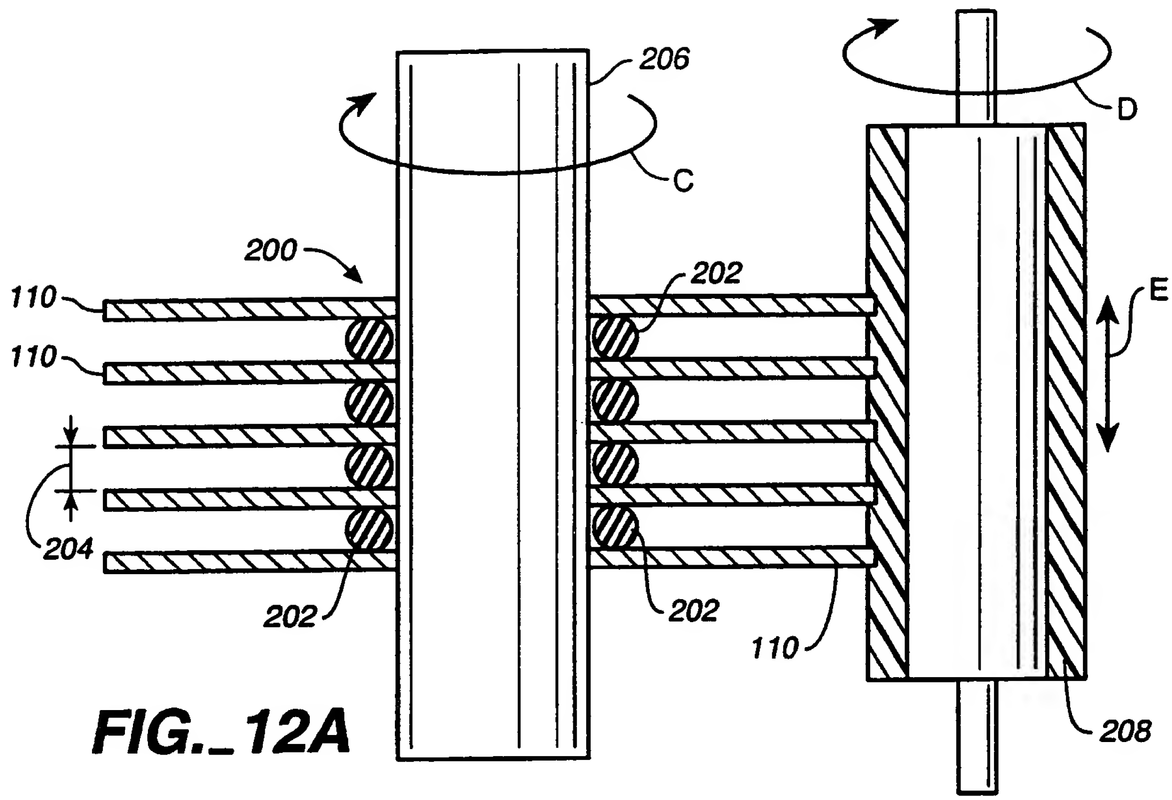

FIG._12A

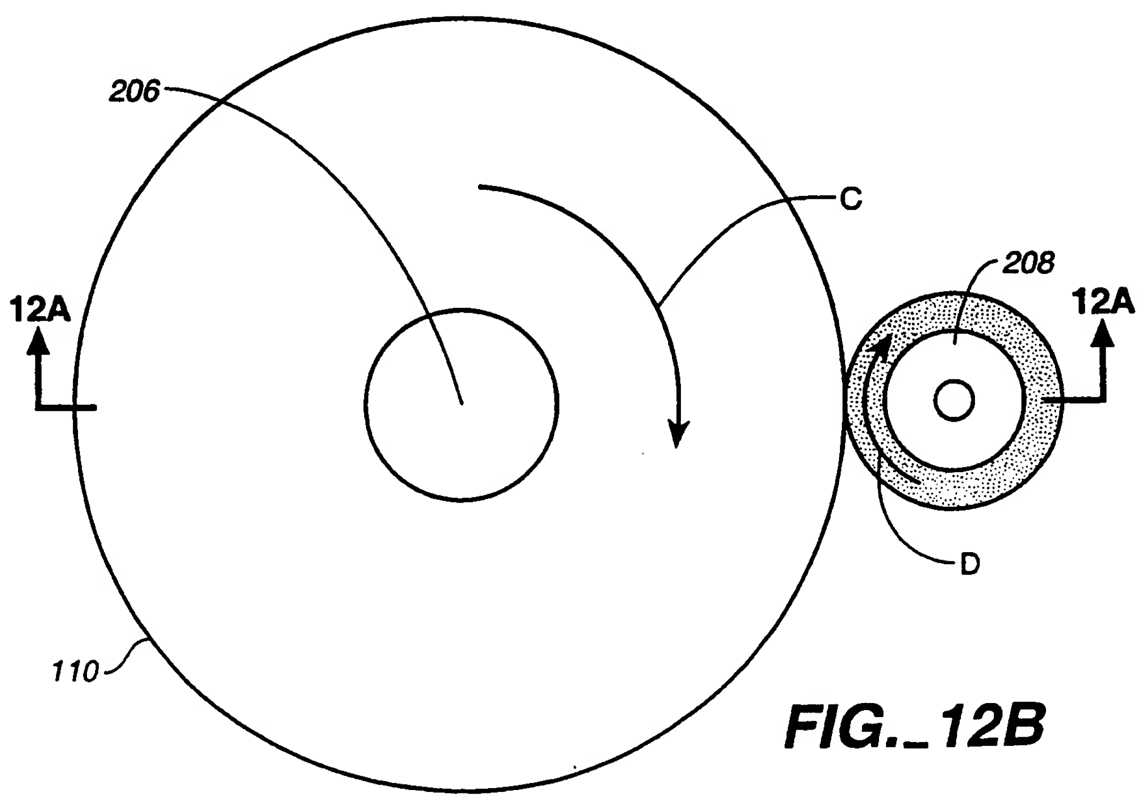

FIG._12B

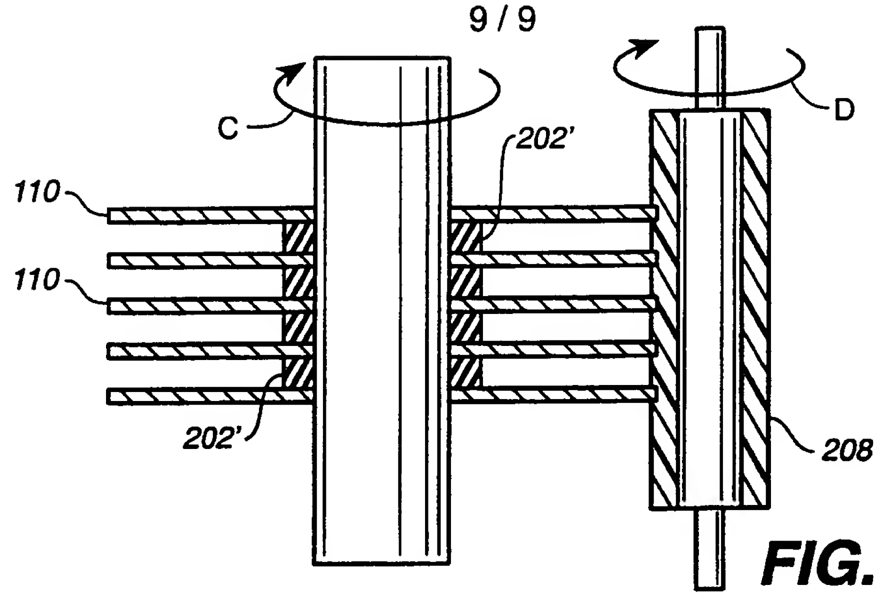

FIG._12A'

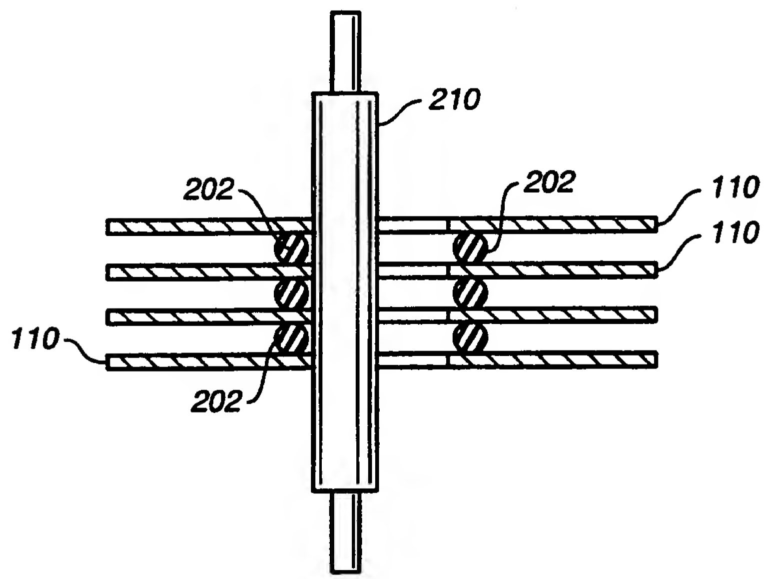

FIG._13A

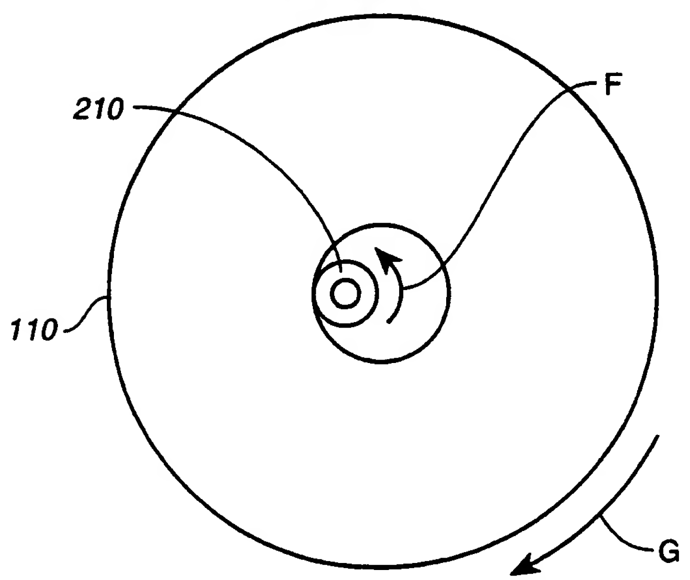

FIG._13B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/21301

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : B23P 17/00; B05D 3/12; B65D 65/28; B24B 19/00; G11B 5/82
US CL : 29/424; 427/289; 428/43; 451/439; 360/135
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 29/527.2 , 412, 424; 451/41, 36, 44, 439; 428/43, 167; 427/289, 154; 360/135

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 5,521,781 A (*KANEKO et al.*) 28 May 1996, See entire document	1-4, 6-8, 10-15, 26, 35 -------- 5, 9, 16
Y,P	US 6,096,405 A (*TAKAHASHI et al.*) 01 August 2000, See col 5, lines 20+	5, 9, 16
X -- Y	US 3,899,314 A (*SIEGMUND*) 12 August 1975, See entire document	17-21, 23, 26 -------- 17-35
Y	US 5,486,276 A (*KITAMOTO et al.*) 23 January 1996, See entire document	17-35

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
05 OCTOBER 2000	23 OCT 2000

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	STEVEN BLOUNT Sheila Veney Paralegal Specialist Technology Center 3700 Telephone No. (703) 305-0319